ADBI Working Paper Series

**WHO BENEFITS FROM PIPED
WATER IN THE HOUSE?
EMPIRICAL EVIDENCE FROM
A GENDERED ANALYSIS IN INDIA**

Ashish Kumar Sedai

No. 1273
June 2021

Asian Development Bank Institute

Ashish Kumar Sedai is a PhD candidate at the Department of Economics of Colorado State University.

The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. Some working papers may develop into other forms of publication.

In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Abstract

The disproportionate burden of water collection, maintenance, and service for women in developing economies calls for a juxtaposition of water infrastructure and gender differences at the household level. We use spatiotemporal data from the largest gender disaggregated human development survey in India (2005–2012) and carry out econometric analyses using individual fixed effects, conditionally exogenous village fixed effects, and instrumental variable regressions to study the effect of indoor piped drinking water (IPDW) on employment and earnings by gender, the self-reported health of women, the prevalence of diarrhea, and children's absence from school. Among others, the results show that a 0.1% increase in village access to IPDW increases the likelihood of women's overall employment by 0.33 percentage points and women's wage/salary employment by 0.39 percentage points, comparatively more than for men. Women's earnings with IPDW increase by 9.9%, their health improves, and children's health and education outcomes improve. Our study recommends evaluating the social demand curve for a piped water supply and/or the consideration of a piped water supply as a right as part of a broader strategy to reduce gender differences.

Keywords: piped water, gender, employment, health, education, India

JEL Classification: Q25, R11, J16, J21

Contents

1. INTRODUCTION

The significance of water accessibility for personal and household use in everyday life is understandable when one does not have access and has to wait for water and/or carry it from a distance. This unproductive burden disproportionately falls on women and children in patriarchal societies in developing economies, where men (typically the household head) choose, or are socially conditioned, to bear the responsibility for putting food on the table, while the women and children are responsible for home production, which involves fetching water and firewood, cleaning, cooking, maintenance, and so on (O'Reilly 2006; Fletcher, Pande, and Moore 2017; Jayachandran 2019). India is one such nation, with one of the lowest average per capita levels of access to clean drinking water (Jessoe 2013): on aggregate, 50% of households still do not have access to piped water.[1] As urban environments grow,[2] low levels of piped water usage not only threaten the welfare of unconnected households (Ashraf et al. 2017) but also pose a large negative externality for the Sustainable Development Goal of reducing gender differences.

Adult women in India, on average, spend 1–2 hours every day collecting and storing water (Fletcher, Pande, and Moore 2017; Ferrant and Thim 2019). Among others, the relationship between water and gender mirrors gender inequalities in various realms, including ownership and control over assets, employment, wages, household division of labor, exposure to and management of risk, access to services, and decision making, all of which are often intertwined with basic household infrastructures, such as access to indoor piped drinking water (IPDW).[3] This issue, in the context of gender differences, that is, women's employment, socioeconomic well-being, and health, is central to resource planning, not only in India but in many low-income nations that struggle to provide households with an adequate and safe water supply. Studies have argued that time wasted on water collection negatively affects women's employment, personal health, child health, and education in developing economies.[4] The argument for employment with piped drinking water in developing economies is the labor time saved from not having to fetch water on a daily basis (Meeks 2017). Among other issues, researchers have also associated the lack of access to water in households with an increase in short-term morbidities (fever, cough, and diarrhea) and the inability to reallocate domestic chores that allows children to attend school (Koolwal and Van de Walle 2013; Dehury and Mohanty 2017).

While India has committed to increasing access to safe drinking water in accordance with Sustainable Development Goal (SDG) 6, the rate of progress has been poor and relatively stagnant (Galiani, Gertler, and Schargrodsky 2005; Wu, Schuyler House, and Peri 2016).[5] In addition, there is little understanding of how the realization of this goal

---

[1] There is often no strong public pressure to improve the service quality of water delivery in India. Customers in many cities do not expect their tap water to be potable and available for 24 hours a day, the water supply in India, both in rural areas and in cities, is only available for a few hours per day, the pressure is irregular, and the water is of questionable quality (McKenzie and Ray 2009). In this regard, the market failure in delivering household water infrastructure in India is astounding.

[2] The United Nations has predicted that the number of city dwellers will rise by 3.5 billion over the next 40 years globally and that 96% of that increase will occur in poor countries.

[3] See Koolwal and Van de Walle (2013), Ferrant, Pesando, and Nowacka (2014), Hulland et al. (2015), Das (2017), and Fletcher, Pande, and Moore (2017).

[4] See Ilahi and Grimard (2000), Koolwal and Van de Walle (2013), UNICEF (2016), Meeks (2017), and Vanaja (2020).

[5] As of 2010, 4,861 of the 5,161 cities/towns in India do not have even a partial sewerage network, and only 21% of the wastewater generated in the country undergoes treatment (Ahluwalia et al. 2011).

could influence SDGs 5 and 10 on gender equality and reduced inequality. Our study sheds light on how access to IPDW affects women's employment and earnings compared with men's and how it affects their health and children's health and educational outcomes. From the data standpoint, our study discusses an important central government scheme for IPDW between 2005 and 2012.

The labor, health, and education questions related to IPDW are the following. Do women with better access to basic infrastructure (IPDW in this instance) tend to participate more in market-based work, earn more, and work more days? Are their children less likely to have short-term morbidities (diarrhea) or miss school? There appears to be little rigorous empirical evidence with which to address these questions at the national level in developing economies. Although Koolwal and Van de Walle (2013) examined the issue of women's labor force participation across developing economies with the proximity of the household to the water infrastructure, their study was cross-sectional in nature and did not fully capture the individual placement and household selection into places with water infrastructure.

Analyzing the National Rural Drinking Water Program (NRDWP) over time with effect from 2009 provided ample variation in the treatment due to a significant increase in the investment outlay from 2009 to 2014 (Wescoat Jr, Fletcher, and Novellino 2016). [6] We used a nationally representative panel of the India Human Development Survey (2005–2012) for the analysis. We transformed an individual-level data set into village-level data by incorporating exogenous village-level characteristics. We used individual and village fixed effects and instrumental variables to control for infrastructure placements and recall bias (Pelz, Chindarkar, and Urpelainen 2021). The fixed effects controlled for all the time-invariant unobserved heterogeneity both for the individual-level analysis and for the village-level analysis. We also used the unique instrument of "non-self community access to IPDW" as an instrument to capture any time-variant unobserved heterogeneity (Vanaja 2020; Sedai et al. 2021; details in the data section). The village fixed effects with exogenous village characteristics allowed us to interpret our point estimates as conditionally exogenous, and the instrumental variable regressions, we argue, provided us with causal point estimates. We then compared these point estimates with the conditionally exogenous point estimates to arrive at a conservative estimate of effects.

The regression coefficients confirm the direction of the hypothesis that IPDW disproportionately benefits women's employment and economic condition, with the magnitudes being higher for village fixed effects and instrumental variable regressions than for individual fixed effects. The point estimate of conditionally exogenous village fixed effects shows that a 0.1% higher average IPDW in the village implies a 0.45 percentage point higher probability of employment of any form (wage, salary, farm, business, animal husbandry, etc.) in rural areas for the overall sample. For men and

---

The author's elaboration from the IHDS and ACCESS survey showed that, between 2005 and 2012, there was a 3.5 percentage point increase in IPDW, while the ACCESS 2015–2018 survey indicated an increase of 0.82 percentage points.

[6] The Eleventh Five Year Plan, 2007–2012, in India identified major issues that needed tackling during the period: the problem of sustainability, water availability and supply, poor water quality, centralized vs. decentralized approaches, and the financing of operation and management costs while ensuring equity in regard to gender, socially and economically weaker sections of the society, school children, socially vulnerable groups such as pregnant and lactating mothers, specially disabled senior citizens, and so on. To address the above issues, the government revised the rural water supply program and guidelines with effect from 4 January 2009 as the National Rural Drinking Water Program (NRDWP) (formerly the Accelerated Rural Water Supply Program (ARWSP), which the Government of India introduced in 1972–73). The project's stated objective was to increase the supply and coverage of potable water to rural communities.

women, these margins are 0.47 and 0.33, respectively. However, moving to non-farm wage and salary employment, a 0.1% higher average IPDW in the village implies a 0.39 percentage point higher probability of employment for women but a smaller and insignificant effect for men.

Among others, a 0.1% higher average IPDW in the village leads to a 2.3% increase in women's annual earnings and a 1.8% increase in men's earnings. A 0.1% higher average IPDW in the village implies that the number of annual work days increases significantly by 9.28 days for women, while men's work days increase by 5.66 days but the effect is insignificant. The individual fixed-effect analysis and instrumental variable regressions confirm these effects. Overall, the disproportionate positive effect of IPDW on women's outcomes seems to be a rural story.

In terms of health, the self-reported health of women significantly improves with IPDW, even with variations in the methods of estimating the outcome of self-reported health. After controlling for other sanitary and hygiene precautions that affect diarrhea, IPDW reduces the likelihood of diarrhea by 0.7 percentage points for poor households and by 0.8 percentage points in urban areas, but no such effect is visible in rural areas. School absence for girls falls by 0.58 days in rural areas and 0.88 days in urban areas, while for boys there is no significant effect in rural and urban areas.

Section 2 discusses the literature on water scarcity for households, the available studies that have highlighted the effect of a household water supply on women's employment, and the studies that have investigated the effect of a household water supply on women's and children's health and educational outcomes. Section 3 discusses the data used in the paper. Section 4 discusses the empirical methodology. Section 5 and 6 presents the results, and section 7 concludes.

2. LITERATURE REVIEW

2.1 Household Water Scarcity in India

According to the 2001 Census of India, the average share of households in a rural district that had access to tap water (inside and outside the residence) ranged from 3% in the eastern state of Odisha[7] to 83% in the northern state of Himachal Pradesh. Not only does access to government-provided water services vary widely across the country but also no rural district in India had 100% access to tap water (Balasubramaniam, Chatterjee, and Mustard 2014). As of 2015, while 87.9% of urban households had access to water for use in toilets, only 42.5% of rural households had this facility (Malakar, Mishra, and Patwardhan 2018). India ranks as one of the poorest countries in the world regarding household water access. In 2001, the per capita annual surface water availability was 1902 m^3, which decreased to 1614 m^3 in 2011 and is likely to reach 1154 m^3 in 2050 (Jain 2011). Adding to the scarcity, water inequality is pertinent in both urban and rural India owing to social (caste) and religious differences, which pose major challenges to the water distribution system. The expectation is that inequality and scarcity of water will increase in the future due to the increasing depletion of groundwater resources and the demand-side pressures due to the expanding urban population (Malakar, Mishra, and Patwardhan 2018).

---

[7] In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

The majority of India's population in rural areas depends heavily on publicly provided water and has to deal with economic hardship due to sustained water shortage. In addition to poverty and inequality, historically persistent social divisions have an intricate link to access to water in rural India (Banerjee, Iyes, and Somanathan 2005).[8] In 2008, no major Indian city had a 24-hour supply of water, with 4 to 5 hours of supply per day being the norm (McKenzie and Ray 2009).[9] In comparison with the Asia and the Pacific region, where the average is 19 hours per day, the reliability of the water supply in India is dismal. Even the averages conceal a great deal of heterogeneity within and between rural and urban areas. In a survey of Delhi households with in-house connections, Zérah (2000) found that only 40% of households in Delhi had a 24-hour supply of water, while more than 25% had under 4 hours of service each day. National-level estimates from the IHDS 2012 survey showed that only 25% of households had a 24-hour supply of indoor piped drinking water, with the average hours of water supply being 6 per day.

In most of urban India, the water supply is only available for a few hours per day, the pressure is irregular, and the water is of questionable quality (McKenzie and Ray 2009). The market failure in the water supply imposes both financial (employment, assets, earnings, and capital costs) and health costs (short- and long-term morbidities) on households (Galiani, Gertler, and Schargrodsky 2005; Hill and Ma 2017; Ambrus, Field, and Gonzalez 2020; Blakeslee, Fishman, and Srinivasan 2020). The survey that Zérah (2000) conducted estimated that each household, on average, spent around 2,000 rupees (Rs) annually coping with the unreliable supply of water, which is 5.5 times as much as they were paying their municipality for their annual water consumption.

In terms of water quality, the study that Hill and Ma (2017) performed in Pennsylvania found that a shale gas plant drilled within 1 kilometer of a community water system increases shale gas-related contaminants in drinking water. However, it is hard to imagine such planned infrastructure placements in populous Indian cities, where the monitoring of water distribution and quality is haphazard (McKenzie and Ray 2009). McKenzie and Ray (2009) found that the groundwater in most urban areas in India exceeded the permissible limits in terms of fluoride, ammonia, and hardness. The municipal water supply in some cities was also high in contaminants. A 2003 survey of 1,000 locations in Kolkata found that 87% of water reservoirs serving residential buildings and 63% of taps had high levels of fecal contamination. Even bottled water is not completely safe. A 2003 study that the Centre for Science and Environment in Delhi conducted, and subsequently repeated in 2006, found that even popular brands of bottled water had high levels of pesticides (McKenzie and Ray 2009).

2.2 Water, Time Use, and Employment

Studies have argued that women in developing economies spend too much time on domestic labor tasks and too little time on other productive tasks, including market-based labor activities (Ferrant, Pesando, and Nowacka 2014; Fletcher, Pande, and Moore 2017). Water supply outages could increase the time that young girls spend on household chores, possibly at the expense of the time that they can spend on schoolwork. In Zambia, Ashraf et al. (2017) found an association between a one

---

[8] To this extent, even pop-up infrastructures for water supply, such as water ATMs, have faced the issue of social division in the access to and distribution of drinking water (Schmidt 2020).

[9] The argument is also valid until 2012; using the IHDS survey, we found that the average number of supply hours of indoor piped drinking water is 3–4 per day.

standard deviation increase in water supply complaints and about 10 minutes more housework per day for young women.

In India, apart from the decreased economic autonomy and access to pooled income, the joint family system increases women's domestic labor (cooking, cleaning, collecting water and fuel, etc.) as the number of household members increases. This is especially true for daughters-in-law or young married women in India, both in rural and in urban areas (Dhanaraj and Mahambare 2019; Anukriti et al. 2020). These issues have led to calls for better-tailored infrastructure investments for women's needs to reduce the time necessary for domestic chores. One such infrastructure is the provision of access to piped water within the household (Ilahi and Grimard 2000; Dinkelman 2011). However, access to water infrastructure at the household level in India is much more than an economic and a logistical issue; disparity and social historicity underscore the access to and ownership of water infrastructure at the household and community levels in India (Sedai, Nepal, and Jamasb 2020).

Household constraints, such as the lack of access to water, electricity, clean cooking fuel, and credit, have limited women's economic opportunities and restricted their contributions to socioeconomic decision making in the household and elsewhere (Anderson and Baland 2002; Anderson and Eswaran 2009; Dinkelman 2011; Aklin et al. 2016; Rathi and Vermaak 2018; Sedai, Nepal, and Jamasb 2020). In developing economies, women appear to be mired in time-consuming domestic chores and child care activities and possess relatively lower bargaining power in household- and community-level decisions than men. Decision making about basic infrastructure provisions—whether among household heads, village leaders, or higher-level authorities—undervalue women's time spent on domestic labor and thus may place inadequate weight on the implications for women (Koolwal and Van de Walle 2013).

Research has widely observed that the income that women earn through labor market participation and entrepreneurship could lead to desirable empowerment and developmental outcomes for women at the household and national levels (Anderson and Eswaran 2009; Sedai et al. 2021). Labor force participation enhances control over economic resources, which could then translate into greater financial independence, higher socioeconomic status, and better bargaining power in the household (Anderson and Eswaran 2009). Studies have also associated women's market work with child welfare, especially for girls, through more equitable investment of women's earnings in the children in the household (Schultz 2001). In these contexts, we argue that (i) reduced time wastage in household chores; (ii) better personal health, which enhances productivity and employability; and (iii) an improvement in child health, which reduces the likelihood of water-borne illnesses and increases school participation, channel the effect of IPDW on women's employment and economic freedom.

2.3 Water, Health, and Education

According to Bartram et al. (2005), far more people endure the largely preventable effects of poor sanitation and water supply than face the effects of war, terrorism, and weapons of mass destruction combined, yet somehow the issue of hygiene and water is the subject of comparatively lower public and political imagination and receives fewer public resources. The irony, as Bartram et al. (2005) also argued, of the water supply issue is that people who can read articles such as this find it hard to imagine defecating daily in plastic bags, open pits, agricultural fields, and public areas for want of a private hygienic alternative (as some 2.6 billion people must do).

In much of the world, especially in developing economies, diseases, such as diarrhea, fever, cough, and respiratory problems, resulting from an inadequate safe water supply are a major public health issue and constraint on development. The most widespread health hazards linked to water are diarrheal diseases, which disproportionately affect young children.[10] The UNICEF (2012) report underscored the need to intensify the global commitment to and funding for the fight against childhood diarrhea and argued that scaling up key interventions among the poorest children would save lives. The key preventive interventions include an improved water supply and the promotion of community-wide sanitation.

In India, where diarrhea is the most common among all developing economies (World Health Organization 2009), it is important to examine the effect of indoor piped drinking water on the likelihood of diarrheal disease among children under the age of 5. Previous research, which Jalan and Ravallion (2003) conducted using the propensity score matching technique to combine two cross-sectional surveys, found that expanding piped water reduces the likelihood of diarrhea in India. They concluded that the prevalence of diarrheal diseases among those without piped water would be 21% higher and the illness duration would be 29% longer than among those with IPDW. However, they also argued that an indoor piped water supply is not a sufficient condition to improve children's health status; the source of ambiguity lies in the uncertainty about how access to piped water interacts with private health inputs, such as hygienic water storage, boiling water, oral rehydration therapy, medical treatment, sanitation, nutrition, and adult women's education and household income (Jalan and Ravallion 2003). In addition, the contamination of drinking water due to the sheer volume of production in cities could cause the level of diarrheal, typhoid, fever, cough, and cholera diseases to rise. In this regard, when analyzing the effect of IPDW on diarrhea, we controlled for the hygiene behavior post access to piped water.

3. DATA

We derived the data that we used for our analysis from the second and third waves of the Indian Human Development Survey (2005–2012) (Desai and Vanneman 2018). The IHDS is a nation-wide multitopic gender-desegregated stratified random sample survey that researchers from the University of Maryland and the National Council of Applied Economic Research (NCAER) in New Delhi carry out jointly (Desai and Vanneman 2018). The IHDS covers wide-ranging topics at the household, individual, village, and school levels on demographic, health, education, and socioeconomic characteristics. The survey covers key gender-disaggregated labor and non-labor market characteristics of employment—wage salary; farm and non-farm employment; annual earnings; work days; self-reported health; incidence of illness, such as diarrhea; and water collection minutes, among others—at the individual level, which are of relevance to our analysis.[11]

---

[10] Kumar and Vollmer (2013), in their study of India using the District Level Household Survey 3, 2008, found that the incidence of diarrhea for children living in a household with improved sanitation is 2.2 percentage points lower than that for children living in a household without improved sanitation. Nearly one in every five child deaths—around 1.5 million a year—is due to diarrhea, which kills more children than AIDS, malaria, and measles combined (Bartram et al. 2005; Wardlaw et al. 2010). Even if it is not fatal, diarrhea may have long-lasting consequences for human health and development, hindering the economic and social potential of the affected societies (Bartram et al. 2005; Ziegelhöfer 2012).

[11] Unlike the National Sample Surveys, which ask for a woman's principal and secondary status activities, the IHDS has separate modules for different types of work (e.g., own farm and non-farm work, wage

The interviewers asked a knowledgeable person, typically the male head of the household, questions related to the socioeconomic status of the household (members), including questions related to income, employment, consumption expenditure, and physical and social capital. They interviewed ever-married women (eligible) between the ages of 15 and 49 in each household about health, education, and gender relations, among others, in the household and community. They asked adolescents between the ages of 15 and 18 about their education, employment, and behavior, among others.

We derived our treatment variable "access to indoor piped drinking water (IPDW)" from the survey item "Does your household have access to indoor piped drinking water?" (yes is 1 and no is 0).[12] After dropping the observations for households without IPDW and individuals below the age of 14, we had a time-balanced sample of 78,751 men and 71,623 women in each round of the IHDS survey.[13]

We took the sample for the analysis of the outcome variable from the individual-level questionnaire, we derived the treatment variable from the household-level questionnaire, and the controls came from the individual-, household-, and village-level questionnaire. To ensure the robustness of the analysis (as the empirical section discusses), we conducted the analysis at the village level, which covered 1410 villages in both rounds of the survey. However, due to missing observations for some variables, we were restricted to 1,386 villages for the rural village-level analysis. It is important to note that the comparison of outcomes between men and women is not necessarily for the same household. The inferences that we drew and compared are not for couples or adults in the same household but for the overall sample.

4. EMPIRICAL MODEL

Why do only some households have IPDW while others do not? It might be the case that households with IPDW are also more forward looking and possess better socioeconomic capital, health, knowledge, habits, and behavior (Kumar and Vollmer 2013; Balasubramaniam, Chatterjee, and Mustard 2014). Both time-variant and time-invariant unobserved heterogeneity affect the selection into or out of IPDW. Given the likelihood of strong endogeneity of access to IPDW (one of the most basic goods for survival), one should clearly not expect to be able to infer the causal impact with confidence (Ravallion 2008; Koolwal and Van de Walle 2013).[14] At least, the panel structure of the IHDS data controls for the time-invariant unobserved heterogeneity

---

and salary labor, and animal husbandry) and asks which household members participated in each type of work during the previous year. In this study, following Chatterjee, Desai, and Vanneman (2018), we considered anyone who worked for at least 240 hours in the previous year across all types of work as being in the labor force.

[12] In addition to IHDS data, we used the ACCESS survey (2015–2018) to examine the recent trends in IPDW in six states (Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, West Bengal, and Odisha). The analysis of descriptive statistics from the ACCESS survey provided inferences regarding the present state of IPDW in relatively poor and populous states in India (Mani et al. 2018; Sedai, Nepal, and Jamasb 2020). Due to the lack of gender-disaggregated data in the ACCESS survey, our regression analysis focused on the variables in the IHDS survey.

[13] The analysis might not have had the same number of observations in the fixed-effect regression. In this regard, we balanced the sample by observations at the beginning of the analysis and not by each outcome variable.

[14] A randomized control trial would not be a feasible option given that our aim was to observe the macro-level effects of the intervention of IPDW. In addition, Ravallion (2008) argued that it is rarely possible to randomize the location of infrastructure projects and related programs, which are core activities in almost any poor country's development strategy.

affecting the treatment. The baseline individual fixed-effect model that we derived from the IHDS is as follows:

$$Y_{it} = \pi Z_{it} + \varphi X_{it} + \delta_i + \sigma_t + \epsilon_{it} \tag{1}$$

Y_{it} is the outcome variable for household i at time t, and Z_{it} is an indicator for access to indoor IPDW. The reference households are those that do not have access to indoor piped drinking water, and the treatment is switching from no access to IPDW to access between 2005 and 2012. X_{it} is a vector of exogenous individual and household characteristics. δ_i captures the household-specific effects. σ_t represents the trend effect. The aim is to estimate the impact of Z_{it} on Y_{it}. However, the problem is that the observed variation in Z_{it} reflects latent factors that also influence Y_{it}.

The fixed effects control for all time-invariant unobserved heterogeneity that could have a correlation with the treatment, such as the household head's caste, location, religion, and cultural characteristics, which are time invariant. Even after controlling for this, there is a strong likelihood that the household-specific differences in treatment, Z_{it}, are endogenous to outcomes due to the time-varying unobserved heterogeneity. Therefore, despite using the household fixed effects, we could not ignore household selection into IPDW due to time-varying unobserved heterogeneity. Within a given locality, some households will have latent preferences, knowledge, or unobserved resources that lead them to have better access to infrastructure than other (observationally similar) households (Koolwal and Van de Walle 2013). The issue of self-selection is concerning when talking about access to basic infrastructure, such as safe drinking water. Any natural or policy shock that the IHDS survey does not cover could affect access to water. The wave dummy σ_t captures any trend changes, but household-specific time-variant heterogeneity could bias the causal estimates.

The standard solution to this problem is to find an instrumental variable (IV) that is correlated with Z_{it} but uncorrelated with outcomes given Z_{it}.[15] Finding an IV for a presumably high degree of selection is a demanding requirement as one can reasonably question whether any observed household characteristic that might influence access to household-specific infrastructure would not also be a relevant determinant of overall outcomes, independently of infrastructure (Ravallion 2008; Koolwal and Van de Walle 2013; Kumar and Vollmer 2013).[16] In addition, the exclusion restrictions that studies should use with the geographic instrumental variables are questionable, given the feedback and spillover effects of an intervention.

Koolwal and Van de Walle (2013) argued that geographic averaging with comprehensive regression controls at the community level for infrastructure placements is a defensible approach. Therefore, following Koolwal and Van de Walle (2013), we addressed the issue of endogeneity by exploiting the geographic differences in infrastructure placements and outcomes while additionally controlling for any community-specific effects over time. This required us to capture adequately the relevant geographic characteristics jointly influencing the outcomes and infrastructure through the vector G_{jt} and any geographic means of X_{it} not included in G_{jt}. The

---

[15] We used a unique instrumental variable from the literature (see Bai et al. 2019; Dang and La 2019; Sedai et al. 2021), which Vanaja (2020) also used in the same context as ours. The instrument captures the average access to IPDW at the community level (village and PSU level), excluding the community of the household in the district of the state at time t (in short, it is the non-self community access to IPDW).

[16] Ravallion (2008) argued that evaluations for development effectiveness focus too much on internal validity (whether researchers draw valid inferences about the impact of that specific project in its specific setting) relative to external validity (whether the researchers draw valid inferences for other projects, either scaled-up versions of that project in the same setting or similar projects in different settings).

incorporation of community-specific effects and time trends presents a layer of robustness additional to the point estimates of Koolwal and Van de Walle's study (2013) as they used cross-sectional data for analysis. We provide this modification to the analysis in equation 1 below:

$$Y_{it} = \pi Z_{it} + \varphi X_{it} + \lambda G_{jt} + \delta_i + \sigma_t + \theta_{jt} + \epsilon_{ijt} \qquad (2)$$

Here, we have added the exogenous community characteristics G_{jt} that affect the IPDW placement, which also includes the community means of X_{it}.[17] In equation 2, the error term has two components, a geographic effect θ_{jt} and an idiosyncratic (household-specific) effect ϵ_{ijt}. The geographic component of the error term sweeps up all the level differences in the error term between areas, so the geographic mean of ϵ_{ijt} vanishes (Koolwal and Van de Walle 2013).[18] All the regressors are exogenous except Z_{it}, which is correlated with ϵ_{ijt} through individual choices, that is, $Cov(Z_{it}; \epsilon_{ijt}/G_{jt}; X_{it}) =/ 0$. Following Koolwal and Van de Walle (2013), we argue that the key identifying assumption is that the endogeneity arises entirely from individual choices within areas such that, when aggregating across individuals within a given area, we can treat access to water as conditionally exogenous; that is, we assume that $Cov(\bar{Z}_{jt}; \epsilon_{jt}/\bar{G}_{jt}; \bar{X}_{it}) = 0$, where the bar over a variable denotes its geographic or community-level mean.

We then aggregated equation 2 over geographic areas, giving the standard "between estimator" over time, as below:

$$\bar{Y}_{jt} = \pi \bar{Z}_{jt} + \varphi \bar{X}_{jt} + \lambda \bar{G}_{jt} + \theta_{jt} \qquad (3)$$

While the household fixed effects that we applied to equation 1 could still yield a biased and inconsistent estimate given that $Cov(Z_{it}; \epsilon_{ijt}/G_{jt}; X_{it}) /= 0$, equation 3 shows that it is possible to identify π through geographic aggregation under our weaker assumption that only the geographic placement is conditionally exogenous. In this regard, we assumed that we have sufficient geographic controls to make it plausible to treat latent geographic effects on outcomes and placement as uncorrelated. Accordingly, we used most of the plausibly exogenous geographic controls that Koolwal and Van de Walle (2013) employed, barring a few as, in addition to their model, we also had the leverage of controlling for the time-invariant unobserved heterogeneity through the village fixed effects and the time trend. Note, however, that we still allowed for endogenous individual placement within areas between 2005 and 2012, whereby there are latent idiosyncratic factors that jointly influence outcomes and individual access to IPDW.

The acceptance of the assumption of conditional exogeneity depends on the available data and the setting. The fixed-effect model controls for geographic mobility both at the individual level and within rural areas. Therefore, our analysis controlled for the residential location choice, which could seriously undermine our identifying assumption. One could collect geographic data relevant to both outcomes and infrastructure placement, but it is justifiable to be skeptical of any claim that one could collect data on latent preference and knowledge parameters at the individual level. In this regard, the ability of our estimation strategy to deal with endogenous placement across individuals within a given area is desirable. Following Koolwal and Van de Walle (2013), we controlled for a wide and rich array of location attributes. However, it was not possible to dismiss the possibility of biases due to unobserved geographic factors entirely.

---

[17] Note that, in the absence of G_{jt} and θ_{jt}, the regression specification in equation 2 is similar to that in equation 1.

[18] The remaining ϵ_i cancels out with δ_i.

Notwithstanding the issues with instruments, as a robustness check of our empirical estimations, following Vanaja (2020), we used the non-self community-level access to IPDW as an instrument. The literature has widely used this instrument to capture the unobserved heterogeneity in infrastructure placements, such as the electricity and water supply (Dang and La 2019; Sedai et al. 2020, 2021; Vanaja 2020). The first-stage estimation is as follows:

$$IPDW_{it} = \rho IPDW_{-jt} + \varphi X_{it} + \delta_i + \sigma_t + \epsilon_{it} \qquad (4)$$

where $\rho IPDW_{-jt}$ represents the non-self community-level access to IPDW. It gives the average village/PSU-level access to IPDW in the district of a state, excluding the village/PSU of the treatment household.

The rationale behind the IV is that, if neighboring villages/PSUs acquire IPDW and realize the economic and social gains of better and safe drinking water, then the status of having no IPDW may signal lower socioeconomic standing; therefore, the expectation is that IPDW in the neighboring districts will increase one's own IPDW (Vanaja 2020; Sedai et al. 2021). We argue that the exogeneity condition for the instrument also holds because IPDW in other communities should not directly affect the labor market differences across genders in one's own community. Following the existing literature, we argue that households' income, the relative bargaining power of the individuals, education, age, and occupational segregation affect gender differences in the labor market (Duflo 2012; Fletcher, Pande, and Moore 2017; Klasen 2019). As we discussed in relation to the potential threats to identification, we anticipate that households' own community-level IPDW and the availability of other infrastructures will have an impact on individual LFP; hence, excluding individuals' home district from the instrument is the key to the exclusion restriction. For the instrument to function, villages/PSUs should be distant from each other, and this implies that the instrument would be weak in satisfying the exclusion restriction. Therefore, we restricted the panel fixed-effect instrumental variable regression to rural areas.

5. RESULTS

5.1 Descriptive Analysis

The descriptive statistics in Table 1 show that the national-level access to IPDW was 26% in 2005 and increased to 30% in 2012. However, for the six relatively poor and populous states in India (ACCESS survey of rural areas), access to IPDW was 5.7% in 2015 and 6.6% in 2018. We also mapped the six states of the ACCESS survey to the IHDS data set and found the same corresponding level of access to IPDW between 2005 and 2012 for the states of Odisha, West Bengal, Uttar Pradesh, Madhya Pradesh, Jharkhand, and Bihar. This is why the use of the IHDS data set did not disregard any recent development in household access to IPDW.

Table 2 shows the descriptive statistics for the IHDS data set, the treatment being access to IPDW between 2005 and 2012. A total of 33% of the households had access to water within their premises in 2005, and a similar figure in 2012, but no access to IPDW. There is no significant difference in water supply hours between households that had and did not have access to IPDW. On average, the walking time to water was around 10–12 minutes for households that did not have IPDW. In 2005, on average, women spent significantly more time on water collection, 73 minutes compared with men's 35 minutes, in households that did not have IPDW. In 2012, the average water collection time was 50 minutes for women and 29 minutes for men with no IPDW.

Choudhuri and Desai (2021) reported that, among households without IPDW, the participation rate in water collection activity was 94.8% among women and 70% among men in 2012.

Table 1: Panel Descriptive Statistics from Two Household Surveys in India, 2005–2018

	2005			2012			
National-level Variables	**Obs.**	**Mean**	**SD**	**Obs.**	**Mean**	**SD**	**T test**
Indoor piped drinking water (0/1)	40,018	0.266	0.442	40,018	0.302	0.459	*
	2015			2018			
Six states of ACCESS							
Indoor piped drinking water (0/1)	8,563	0.057	0.232	8,563	0.066	0.248	–

Author's elaboration; IHDS (2005–2012); ACCESS survey (2015–2018). The ACCESS survey is for the rural areas in the six relatively poorer states in India, namely Madhya Pradesh, Uttar Pradesh, Odisha, Bihar, Jharkhand, and West Bengal. Note: We checked the six states' average of the ACCESS survey with the IHDS survey for consistency and the averages between 2005 and 2012 are similar to the averages between 2015 and 2018.

Table 2: Descriptive Statistics by Treatment and Time: Access to Indoor Piped Drinking Water (IDPW), India, 2005–2012

	2005				2012			
	No IDPW		**IDPW**		**No IDPW**		**IDPW**	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Water								
Water in the house	0.33	0.47	1.00	0.00	0.32	0.47	1.00	0.00
Water supply hours	4.23	6.14	4.92	6.38	3.88	5.35	4.18	5.78
Walking time to water	10.35	10.57	0.00	0.00	10.43	12.30	0.00	0.00
Work								
Employment (>30 days)	0.40	0.49	0.36	0.48	0.47	0.50	0.44	0.50
Wage/salary employment (0/1)	0.24	0.43	0.20	0.40	0.32	0.46	0.28	0.45
Annual work days	201.93	98.66	243.82	95.62	200.47	110.97	242.11	105.83
Health and education								
Self-reported health (0–5)	2.26	0.81	2.18	0.76	2.19	0.87	2.02	0.84
Diarrhea in the last month	0.03	0.17	0.01	0.12	0.02	0.15	0.02	0.13
Days absent from school (30 days)	3.38	5.79	1.81	3.96	3.95	5.26	2.94	5.04
Observations	109,700		40,676		103,969		46,340	

Author elaboration; IHDS (2005–2012).

There is no significant difference in aggregate employment for households with and without IPDW for both years. Households without IPDW tend to have slightly higher employment (wage/salary farm business and animal husbandry) than households with IPDW. Similarly, households without IPDW tend to have a slightly higher likelihood of having wage/salary employment (24% in 2005 and 32% in 2012) than households with IPDW (20% in 2005 and 28% in 2012). However, households with IPDW tend to have more annual work days than households without IPDW. Descriptively, there is no significant difference in self-reported health for women with and without access to IPDW. For children, the likelihood of having diarrhea (past month) is slightly lower in households with IPDW than in households without IPDW in 2005, and there is no such difference in 2012. However, the number of days that a child missed school in the last month is significantly lower in households with IPDW than in households without IPDW.

Figure 1: Descriptive Statistics of Access to Water and Water Collection by Gender, 2005–2012
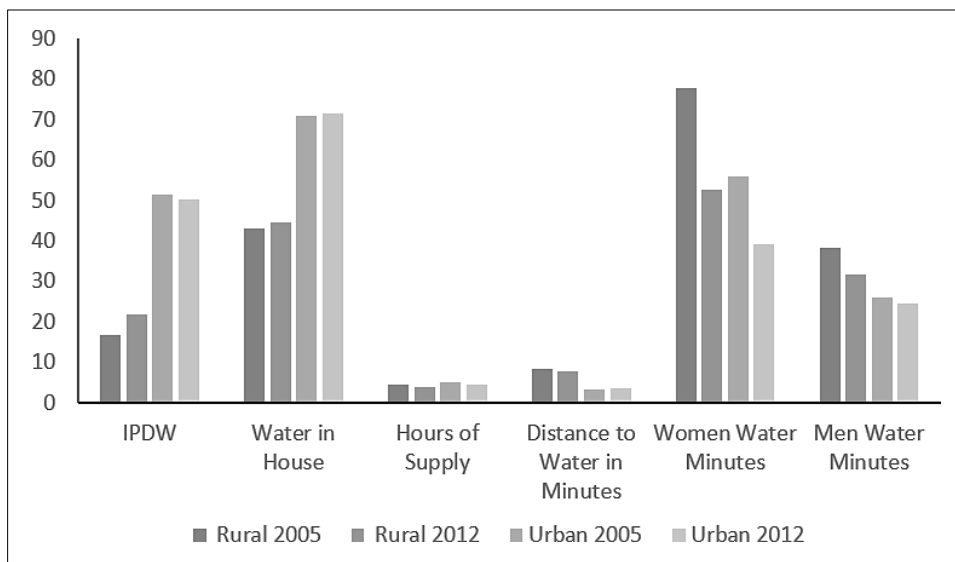
Note: IPDW and water in the house are in percentages. Hours of water supply and water collection minutes are daily averages.
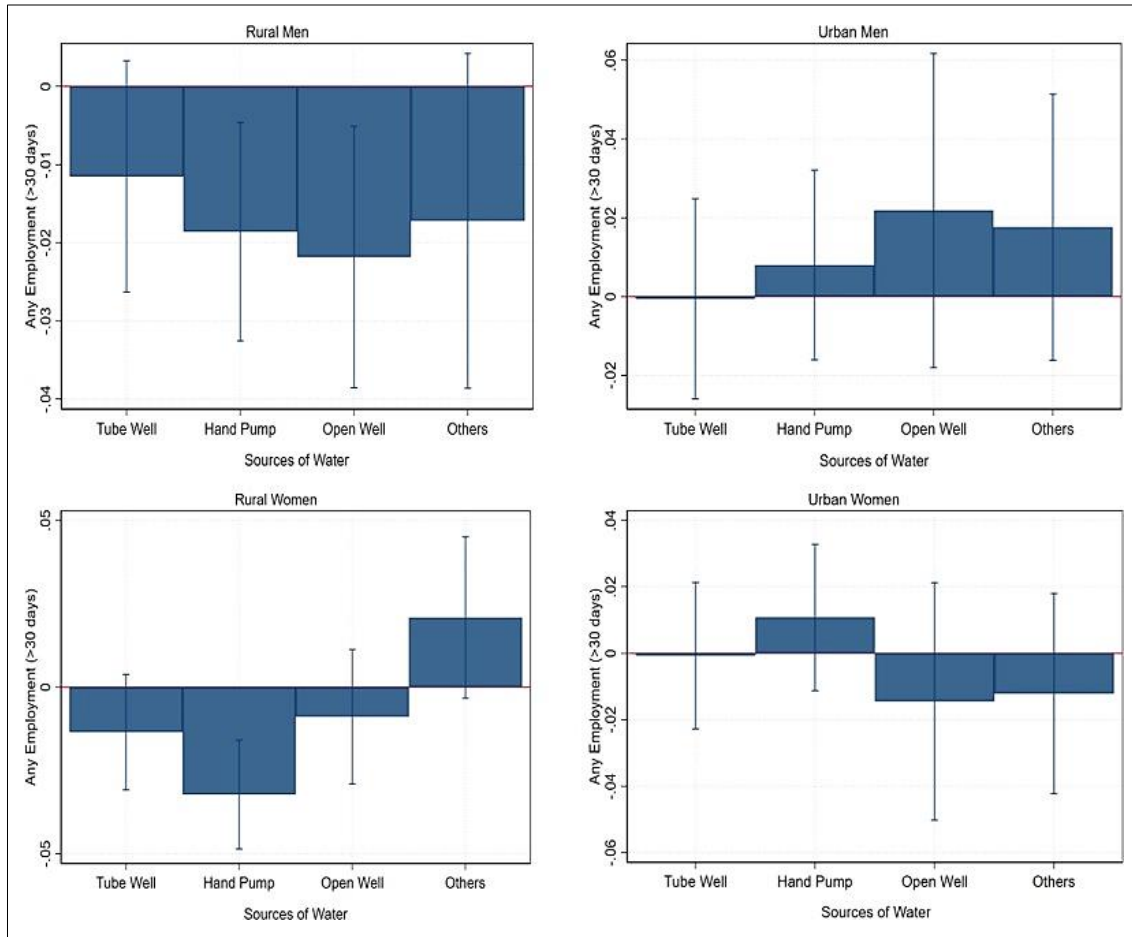
Source: Author's calculations; IHDS (2005–2012).

Figure 1 shows the access to IPDW, water within house, water supply hours, distance to water in minutes, and men and women's daily water collection minutes from the IHDS survey. The figure shows that there was a significant increase in rural IPDW (in percentage) between 2005 and 2012, highlighting the effect of the revised National Rural Drinking Water Programme, effective 2009 which focused on rural household water supply, moving away from community water infrastructure provisioning. In urban areas there is no significant difference in access to IPDW. There was no significant change in the availability of water supply within the household premises both in rural and urban areas.

Figure 2 shows the fixed-effect estimate of sources of water on any employment (farm business, wage/salary, animal husbandry) for men and women in rural and urban areas. For the analysis, we controlled for the time trends, the individual specific effects, and the month of the interview. The main sources of water are piped water, which is the base category in the fixed-effect regression, tube well, hand pump, open well, and all others.[19] The results show that having hand pumps as a source of water for the household has a significant negative effect on both men's and women's employment in both rural and urban areas. For men, open wells also have a significant negative effect on their employment in rural areas. In urban areas, the sources of water in comparison with piped water do not yield any significant differences.

---

[19] All other categories of sources of water include covered wells, rainwater, tankers, bottled water, and so on. All of these sources together account for less than 5% of the overall sources of water and hence we combined them in the "other" category.

**Figure 2: Panel Fixed Effects: Source of Water and Employment
by Gender and Location**

Source: Author's calculations; IHDS (2005–2012). In the individual fixed-effect regression, we controlled for the time trend and the month of the interview.

5.2 IPDW, Time Use, and Employment

Table 3, using the individual fixed effects, shows the association between IPDW and women's daily water collection minutes, controlling for household and individual characteristics (in the footnote to the table). The analysis shows that IPDW has a significant relationship with water collection minutes for women, especially for those in poor households and in rural areas. Column 6 of Table 3 shows that there is an association between IPDW and 20 minutes' reduction in the time spent collecting water for women from poor households. For the whole sample, the reduction in daily water collection minutes is 7 minutes a day.

Following Ashraf et al. (2017), who used primary time use data for the city of Lusaka to assess the total time spent on chores, we added fuel and water collection minutes.[20] We found that having access to IPDW reduces the daily fuel and water collection time by 31 minutes for women in poor households. Ashraf et al. (2017), in Lusaka, found that a one standard deviation increase in days with supply issues increased the hours of chore work by 0.171 hours (10.26 minutes).

---

[20] As they are the only two variables that have responses in minutes of a day.

Table 3: Panel Fixed Effects: Indoor Piped Drinking Water and Women's Daily Water Collection Time in Minutes, IHDS, 2005–2012

Variables	(1) All	(2) All	(3) Rural	(4) Urban	(5) Non-poor	(6) Poor
Indoor piped drinking water	–7.416***	–3.954*	–5.922**	5.918	–1.277	–20.187***
	(2.345)	(2.412)	(2.777)	(5.005)	(2.622)	(6.250)
HH, ind., com. controls	N	Y	Y	Y	Y	Y
Observations	105,278	98,203	79,497	18,706	74,590	23,482
Number of individuals	71,638	68,346	54,412	14,178	52,877	15,362

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We interpreted coefficients as percentage point changes. Panel(a) shows the effect of access to indoor piped drinking water on water collection minutes. Additional independent variables in all the regressions: availability of electricity in the house, any public program for sanitary toilets, individual's age, age squared, marital status, education, household size, log per capita consumption, wave dummy, and social networks with teachers, educators, health practitioners, lawyers, government officials, and local political leaders.

Table 4 presents the main results on the effects of IPDW on overall employment and wage/salary employment for both men and women in rural and urban areas using individual fixed effects and village fixed effects. In Table 4 and all the remaining analyses using village fixed effects, the exogenous village characteristics that we controlled for are a panchayat bhavan (local governance authority office) in the village (0/1), the percentage of households with electricity in the village (0/1), an agricultural co-operative in the village (0/1), a government or private school in the village (0/1), the distance to a bank in kilometers from the village, the presence of an informal credit association in the village (0/1), a paved road in the village (0/1), the distance to a bus station in kilometers from the village, the sowing and harvesting market wage for the Rabi and Kharif seasons for men and women in the village, and the presence of a market (bazaar) in the village.

Panel (a) shows the panel individual fixed effects: having access to IPDW increases women's likelihood of any employment (≥ 30 days) by 1.7 percentage points (pp) and men's likelihood of employment by 1.3 pp in rural areas. There is no such effect in urban areas. In terms of wage/salary employment, the fixed-effect model indicates that access to IPDW increases women's likelihood of employment by 1.5 pp overall and by 2.9 pp in rural areas. There is no such effect for men either in rural or in urban areas. This shows that the employment gains for women from IPDW are not limited to farm employment or self-employment; the gains are visible in wage/salary employment, which, as Anderson and Eswaran (2009) argued, is critical for women's economic and social autonomy. Ashraf et al. (2017), for Lusaka, Zambia, found that a one standard deviation increase in water supply complaints results in around 10 minutes more housework per day for young women.

The village fixed-effect results in panel (b) for rural areas, which, as we discussed in the empirical section, are conditionally exogenous, show that a 0.1% higher average access to IPDW in the village implies a 0.47 percentage point higher probability of overall employment (farm, business, wage, salary, and animal husbandry) for men in rural areas and a 0.33 percentage point higher probability of employment for women in rural areas. However, in terms of wage and salary employment (a subset of overall employment), a 0.1% higher average access to IPDW in the village implies a 0.39 percentage point higher probability of wage/salary employment for women. The effect is smaller, 0.10 percentage points, and insignificant. Koolwal and Van de Walle (2013) also observed an increasing trend in women's share of off-farm employment compared with men's employment during 1996/1997.

Table 4: Panel Fixed Effects: Households' Access to Indoor Piped Drinking Water in Any Employment (Wage and Salary Farm Business) (greater than 30 days) and Only Wage and Salary Employment by Gender in Rural and Urban India, 2005–2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Men	Men	Women	Women
Variables	All	Men	Women	Rural	Urban	Rural	Urban
Panel (a): Individual FE							
Any employment (>30 days)							
Indoor piped water	0.004	0.003	0.005	0.013**	−0.013	0.017**	−0.010
	(0.004)	(0.005)	(0.005)	(0.006)	(0.008)	(0.008)	(0.007)
Wage/salary employment							
Indoor piped water	0.008**	0.002	0.015***	0.008	−0.016	0.029***	−0.008
	(0.003)	(0.005)	(0.005)	(0.007)	(0.008)	(0.006)	(0.006)
Ind. and HH controls	Y	Y	Y	Y	Y	Y	Y
Observations	209,860	111,061	98,799	74,901	36,160	67,534	31,265
Number of individuals	119,054	62,863	56,193	43,033	20,982	38,626	18,054
Panel (b): Village FE (rural)							
Any employment (>30 days)							
Indoor piped water	0.045***	0.047***	0.033*				
	(0.014)	(0.014)	(0.019)				
Wage/salary employment							
Indoor piped water	0.025	0.010	0.039**				
	(0.016)	(0.017)	(0.018)				
Village fixed effects	Y	Y	Y				
Village controls	Y	Y	Y				
Observations	2,510	2,509	2,507				
Number of PSUs	1,386	1,385	1,383				

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports the percentage point effect of access to piped drinking water within the house on any paid employment for over 30 days in a year. For panel (a), additional independent variables in all the regressions are household electricity access, any public program for sanitary toilets, household size, any social networks or acquaintance with doctors and health care workers, teachers, school workers, politicians, police, military, and government officials, individual's age, age squared, marital status, and adult male and female education. Panel (b) (rural areas) uses all the controls in panel (a) (excluding electricity access and marital status). In addition, we controlled for the presence of a local governance body (Panchayat Bhavan) in the village, the percentage of households with electricity in the village, an agricultural co-operative in the village, a government or private school in the village, the distance to a bank in kilometers, the presence of informal credit associations in the village, a paved road in the village, the distance to a bus station in kilometers in the village, the sowing and harvesting market wage for the Rabi and Kharif seasons for men and women in the village, and the presence of a market (bazaar) in the village.

Table 5 shows the effect of access to IPDW on annual earnings after controlling for the number of hours worked annually. In panel (a), the individual fixed-effect coefficients highlight that access to IPDW increases annual earnings by 7.5% for the aggregate sample. The effect is stronger for women: a 9.9% increase in annual earnings compared with 6.6% for men. However, the increased annual earnings for women are observable only in rural areas, with an 11.8% increase, while in urban areas there is no significant effect on the earnings of women with IPDW. Men, on the other hand, have increased earnings both in rural and in urban areas with IPDW, with rural men gaining larger increases than urban men.

Table 5: Panel Fixed Effects: Households' Access to Indoor Piped Drinking Water and Log of Real Annual Earnings, by Gender, in Rural and Urban India, 2005–2012

Variables	(1) All	(2) Men	(3) Women	(4) Men Rural	(5) Men Urban	(6) Women Rural	(7) Women Urban
Panel (a): Individual FE							
Indoor piped water	0.075***	0.066***	0.099***	0.069***	0.049***	0.118***	-0.036
	(0.013)	(0.013)	(0.030)	(0.018)	(0.018)	(0.034)	(0.058)
Log annual work hours	0.713***	0.740***	0.660***	0.750***	0.688***	0.659***	0.657***
	(0.008)	(0.009)	(0.013)	(0.010)	(0.024)	(0.014)	(0.049)
Observations	124,836	85,244	39,592	59,827	25,417	33,622	5,970
Number of individuals	80,957	52,744	28,215	37,184	16,312	23,506	4,752
Panel (b): Village FE							
Indoor piped water	0.197***	0.180**	0.234*				
	(0.074)	(0.078)	(0.129)				
Log annual work hours	0.451***	0.529***	0.556***				
	(0.054)	(0.063)	(0.069)				
Observations	2,507	2,505	2,432				
Number of villages	1,386	1,385	1,364				

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports the percentage effect of access to piped drinking water within the house on the log of real annual individual earnings. All additional controls are as we presented in Table 4.

Panel (b) shows the conditionally exogenous village fixed-effect results in rural areas. The results corroborate the individual fixed-effect results in that a 0.1% higher average access to IPDW in the village implies 0.19% higher annual earnings for the aggregate sample, 0.18% higher annual earnings for men, and 0.23% higher annual earnings for women in rural areas. The results showing stronger positive effects on both employment and earnings for women could be due to the low base to begin with as men on average have higher levels of employment and earnings than women. In addition, the time conservation argument with IPDW for disproportionately burdened women could be a significant criterion for higher employment gains for women. Nevertheless, access to IPDW, as we observed, seems to reduce the gender differences in economic autonomy between men and women, especially in rural India, where the IPDW infrastructure is lacking comparatively more than in urban areas.

Table 6 shows the effect of IPDW on annual work days by gender in rural and urban areas. Panel (a) shows the individual fixed-effect regression results, and panel (b) contains the conditionally exogenous village fixed-effect results.

In panel (a), access to IPDW increases the annual work days by 1.36 days on aggregate. The increase is 6.9 days for women in rural areas; in urban areas, there is no significant effect. For men, there are no significant effects in rural and urban areas. The estimates point to increasing work days with IPDW primarily for women. In panel (b), the village fixed-effect regression in rural areas shows that a 0.1% higher average access to IPDW in the village implies 9.2 more annual work days for women. Here, again, the effect on men is smaller and insignificant. Overall, the results for employment, time use, and earnings indicate that IPDW has the potential to reduce gender differences in employment, earnings, and home production. The relatively better individual-level economic outcomes for women with IPDW could be critical for empowering women, especially in rural India.

Table 6: Panel Fixed Effects: Households' Access to Indoor Piped Drinking Water and Annual Work Days, by Gender, in Rural and Urban India, 2005–2012

Variables	(1) All	(2) Men	(3) Women	(4) Men Rural	(5) Men Urban	(6) Women Rural	(7) Women Urban
Panel (a): Individual FE							
Indoor piped water	1.362***	0.622	5.279***	2.186	-2.491	6.902***	-5.114
	(1.131)	(1.282)	(2.425)	(1.754)	(1.721)	(2.649)	(5.966)
Observations	129,410	87,415	41,995	61,795	25,620	35,877	6,118
R-squared	0.660	0.659	0.693	0.687	0.579	0.710	0.589
Number of individuals	82,752	53,427	29,327	37,798	16,397	24,530	4,844
Panel (b): Village FE (rural)							
Indoor piped water	6.265	5.664	9.288**				
	(6.486)	(6.696)	(4.385)				
Observations	2,510	2,508	2,450				
Number of villages	1,386	1,385	1,367				

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All additional controls are as we presented in Table 4.

6. IPDW HEALTH AND EDUCATION

In this section, we discuss the effects of IPDW on the self-reported health outcomes for adult women, the likelihood of diarrhea in the household in the past month, and the school absence of children in the past month. We used fixed effects, which constrain the location choice of households closer to IPDW, and controlled for any time trend and/or recall bias. In addition, we extensively controlled for household time-varying factors that could affect access to IPDW, such as per capita income, education, household size, public programs for sanitation (latrines/toilets), a wide range of social networks, electrification, and any time trends. [21] Having said this, we cannot be absolutely sure of the causal effect. There could be some time-varying omitted variable that could correlate with the error term and IPDW. Hence, we interpret our point estimates as associations rather than effects.

Table 7 shows the effect of IPDW on women's self-reported health. We made two classifications of self-reported health: (i) we considered good and very good health as equal to 1 and assigned poor, very poor, and acceptable health the score 0, with a positive mindset of improving the state of health with IPDW; and (ii) we considered good, very good, and acceptable health as equal to 1 and assigned poor and very poor health the score 0, with a normative mindset of maintaining the standard of health with IPDW.

In the first scenario, the individual fixed-effect analysis shows an association between access to IPDW and a 1.63 percentage point increase in women's health in rural areas. The associations for urban, poor, and non-poor women are positive but insignificant. As we expected, in the second case, moving from poor health to acceptable health and above (normative case), having IPDW has significant positive associations with health for both rural and urban and both poor and non-poor women. The strongest association is 6.86 percentage points for poor women. In the second scenario, there are no significant differences in health outcomes for women in rural and urban areas, the associations being 3.16 and 3.52 percentage points, respectively.

---

[21] We used slightly separate controls for the self-reported health, diarrhea, and school absence analyses.

Table 7: Panel Fixed Effects: Households' Access to Indoor Piped Drinking Water and Women's Self-Reported Health, 2005–2012

Variables	(1) All	(2) Rural	(3) Urban	(4) Poor	(5) Non-poor
Individual FE Good and v. good = 1, satisfactory, poor, and v. poor = 0					
Indoor piped water	0.0294**	0.0316**	0.0352*	0.0686*	0.0241*
	(0.0122)	(0.0154)	(0.0200)	(0.0379)	(0.0128)
Good, v. good, and satisfactory = 1, poor and v. poor = 0					
Indoor piped water	0.00974	0.0163*	0.000689	0.00115	0.0102
	(0.00662)	(0.00840)	(0.0110)	(0.0198)	(0.00704)
Observations	47,225	32,527	14,698	7,819	39,402
Number of individuals	24,909	17,196	7,713	4,133	20,772

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports the percentage point effect of access to piped drinking water within the house on the self-reported health of women (respondents from the eligible women's questionnaires of IHDS, 2005– 2012). Additional independent variables in all the regressions: availability of a water source within the house premises, household electricity access, any public program for sanitary toilets, individual's age, marital status, education, household size, and any social networks or acquaintance with doctors and health care workers, teachers, school workers, politicians, police, military, and government officials.

There is an intricate link between household IPDW and health outcomes, both directly and indirectly. The direct impact of water disruptions is that families may substitute less clean water, which should increase the prevalence of water-borne illnesses (Ashraf et al. 2017). For women, due to the large amount of time spent in the household (Fletcher Pande, and Moore 2017; Sedai et al. 2021), the impact of water disruptions could well extend beyond water-borne illnesses to highly contagious diseases (for instance respiratory issues, intestinal worms, or malaria) due to the lack of water for hand washing and consumption. The study by Ashraf et al. (2017), in Lusaka, Zambia, associated a one standard deviation increase in outstanding supply complaints with 57 extra cases of respiratory infections and .83 extra cases of the measles, increases of 13% and 18%, respectively.

Table 8 shows the association between IPDW and the likelihood of diarrhea for the full sample. In addition to the controls that we used in the previous analyses, we included two additional controls, purifying water (0/1) and storing drinking water with a lid (0/1), which could affect the likelihood of diarrhea regardless of the sources. Diverging from the previous specifications for the gendered analysis, in the case of diarrhea, we analyzed the full sample, the rural–urban sample, and the poor and non-poor sample. The individual fixed-effect analysis shows that having access to IPDW has a negative association with the likelihood of diarrhea in the past month by 0.2 percentage points for the overall sample. We found a significant association of IPDW with the reduction of the likelihood of diarrhea in urban areas but no significant associations in rural areas.

Our finding is in line with McKenzie and Ray's (2009) meta-analysis of the literature; they argued that, in India, the surface-level contamination of water that could lead to diarrheal disease, among others, is higher in urban areas than in rural areas. Hence, we anticipated a greater negative association between IPDW and diarrhea cases in urban areas. The fixed-effect analysis also shows that access to IPDW has a significant association with the reduction of diarrheal disease for poor households, the coefficient being 0.7 percentage points, while no significant association exists for non-poor households. Similar to our study, Ashraf et al. (2017) found that a one

standard deviation increase in outstanding supply complaints (24 days) led to an increase of 24 cases of diarrhea and .05 cases of typhoid fever, increases of 12% and 22%, respectively.

Table 8: Indoor Piped Drinking Water and the Likelihood of Diarrhea, India, 2005–2012

Variables	(1) All	(2) Rural	(3) Urban	(4) Poor	(5) Non-poor
Indoor piped drinking water	−0.002**	0.001	−0.008***	−0.007**	−0.002
	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)
Store drinking water with lid	−0.004***	−0.004**	−0.004*	−0.007**	−0.003*
	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)
Wave dummy	−0.007***	−0.009***	−0.004*	−0.016***	−0.004**
	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
HH and individual controls	Y	Y	Y	Y	Y
Observations	251,288	171,960	79,328	47,197	204,048
Number of individuals	139,496	96,768	44,732	26,151	113,302

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Additional independent variables in all the regressions: dummy for water purification, wave dummy, log of per capita consumption, electricity access, any public program for sanitation (latrines/toilets), adult male education, adult female education, household size, age of the respondent, and networks with doctors, hospitals, and health care workers, teachers, educators, government officials, and local politicians.

Next, we analyzed the association between IPDW and school absence for boys and girls under the age of 15 for the overall sample and in rural and urban areas. The individual fixed-effect analysis shows that access to IPDW has a negative association with school absence in the past month, the negative association, as expected, being stronger for girls than for boys.

Table 9: Panel Fixed Effects: Effect of IPDW on Absence from School in the Past Month, India, 2005–2012

Variables	(1) All	(2) Boys	(3) Girls	(4) Boys	(5) Boys	(6) Girls	(7) Girls
Indoor piped drinking water	−0.437**	−0.272	−0.640***	−0.212	−0.453	−0.568*	−0.882**
	(0.174)	(0.243)	(0.246)	(0.323)	(0.379)	(0.312)	(0.417)
Wave dummy	1.389***	0.827*	2.061***	0.739	0.787	1.369**	2.661**
	(0.355)	(0.470)	(0.547)	(0.575)	(0.888)	(0.632)	(1.036)
Observations	54,446	30,305	24,141	20,738	9,567	16,358	7,783
Number of individuals	42,421	23,732	18,690	16,471	7,424	12,883	5,956

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Additional independent variables in all the regressions: water stored with a lid, log of per capita consumption, electricity access, any public program for sanitation (latrines/toilets), adult male education, adult female education, household size, age of the respondent, and networks with doctors, hospitals, and health care workers, teachers, educators, government officials, and local politicians.

**Table 10: Panel Instrumental Variable Regression: Effect of IPDW
on Employment in Rural India, 2005–2012**

	(1)	(2)	(3)	(4)	(5)
Variables	**All**	**Poor**	**Non-poor**	**Men**	**Women**
Treatment: IPDW in rural areas					
Any employment (>30 days)	0.079***	0.086***	0.069***	0.062***	0.090***
	(0.020)	(0.048)	(0.023)	(0.025)	(0.033)
Wage and salary employment	0.068***	0.058**	0.062***	0.048***	0.073***
	(0.020)	(0.049)	(0.022)	(0.028)	(0.029)
F test (instrument)	1,966	473	1,429	1,088	908
Observations	140,197	27,703	112,470	73,705	66,492
Number of individuals	80,373	15,826	64,523	42,336	38,037

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Additional independent variables in all the regressions: age, age squared, marital status, individual's education, household size, log of per capita household consumption, electricity access, public program for sanitation, networks with doctors, hospitals, and health care workers, politicians, educators, and government officials. The instrument that we used is the average non-self community-level access to IPDW in rural areas. The Sanderson–Windmeijer multivariate F test of excluded instruments showed that the instrument is strong (Staiger and James 1997).

**Table 11: Access to Piped Drinking Water, Water within the House,
and Water Supply Hours by Asset Quintiles: Percentage by Relative Asset
Levels, 2005–2012**

	Poor	Lower Middle	Middle	Upper Middle	Richest
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
2005					
Indoor piped drinking water	0.02	0.06	0.19	0.38	0.62
	(0.13)	(0.25)	(0.39)	(0.49)	(0.49)
Water within the house	0.19	0.28	0.42	0.65	0.88
	(0.39)	(0.45)	(0.49)	(0.48)	(0.32)
Water supply hours	3.26	3.97	4.33	4.62	5.09
	(5.05)	(5.94)	(6.25)	(6.24)	(6.34)
2012					
Indoor piped drinking water	0.04	0.13	0.26	0.44	0.62
	(0.20)	(0.34)	(0.44)	(0.50)	(0.49)
Water within the house	0.21	0.33	0.47	0.67	0.88
	(0.41)	(0.47)	(0.50)	(0.47)	(0.32)
Water supply hours	3.48	3.91	3.77	4.00	4.33
	(5.02)	(5.66)	(5.45)	(5.52)	(5.80)
Observations	7,723	6,801	9,639	7,888	7,780

Source: Author's elaboration; IHDS (2005–2012).

Table 12: Panel Fixed Effects: Indoor Piped Drinking Water and Women's Daily Water Collection Time in Minutes by Region, IHDS, 2005–2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	**Hills**	**North**	**North Central**	**Central Plains**	**East**	**West**	**South**
Indoor piped water	17.571	–9.376	–13.98*	–10.98**	–5.844**	–21.50***	2.021
	(3.789)	(39.01)	(7.178)	(5.227)	(2.473)	(6.486)	(4.008)
Observations	6,665	4,343	17,519	24,836	16,713	12,680	22,931
Number of individuals	4,958	3,697	12,439	17,100	11,991	9,522	17,166

Robust standard errors (clustered at the individual level) in parentheses; p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports the effect of access to piped drinking water in minutes. An additional independent variable in all the regressions is the individual's marital status. States according to regions—Hills, North, North Central, Central Plains, East, West, South. Note that some of the states are Union Territories; the classification follows IHDS (2005–2012).

Access to IPDW has an association with 0.43 fewer days of absence from school for the overall sample. For girls, the association is 0.64 fewer days of school absence in a month. The association is also more pronounced for urban girls than for rural girls, with 0.88 and 0.56 fewer days of school absence in the past month, respectively. There is a negative association between IPDW and school absence for boys both in rural and in urban areas; however, the association is insignificant. The wave dummy, as we expected, shows that, with higher levels of classes, the days of absence increase for the sample, especially for girls, as they are increasingly responsible for home production.

7. CONCLUSION, LIMITATIONS, AND POLICY

This study examines the effects of access to indoor piped drinking water on gender differences in general employment, wage and salary employment, amount of annual earnings, and annual work days between men and women in India. In addition, the study examines the effect of indoor piped water on the likelihood of incidence of diarrhea, and the likelihood of child school absence. The study is a first in India to use the longitudinal analysis approach, which controls for time invariant factors that could affect selection into piped water in the household, and any systematic recall bias. In addition, the study is the first one at the national level which allows for a comparison of rural–urban effects of indoor piped water on gendered outcomes. The study uses three empirical strategies to arrive at a conservative point estimate of effects which could be policy relevant. To control for arguments of self-selection which is imperative in basic household infrastructures, such as access to water, we use conditionally exogenous (village fixed effects) and instrumental variables regressions. The study finds indoor piped water to be critical in reducing gender differences in employment with women disproportionately benefiting from access to piped water in the house in terms of employment opportunities both on and off the farm.

After controlling for the process of water purification and storage, we found significant decreases in diarrhea with access to indoor piped water, suggesting that indoor piped water is a superior substitute to other sources of drinking water for the house, both in terms of employment and health. Any other source of water is found to be inferior to piped drinking water in terms of its effects on employment for both men and women, as was also found by Ashraf et al. (2017) in Lusaka, Zambia. Having access to piped water affects many daily needs, therefore there are significant costs to not having it. For families with fewer resources, the substitutes: hand sanitizers, bottled water, or gym showers are hard to come by, and therefore a policy solution to supply adequate

drinkable water through pipes should be a priority if human development is of significant concern. Results show that when piped water is lacking, women's economic freedom is lower than what it could be. Increase in adult women's employment and earnings through adequate provisioning of basic infrastructures—water, electricity, toilets, gas—could be a welcome increase in consumption at the national level, potentially better technology and standard of living. If the poorer people could be protected from the drudgery of water collection from open wells, bore holes, civic taps, etc., it could go a long way in reducing economic inequality. Given the consistency in the effect of piped water on women's socioeconomic outcomes in developing economies, lacking access to piped water could in fact be a crucial determinant of differences in women's socioeconomic outcomes between developed and developing economies.

REFERENCES

Ahluwalia, I. J., N. Munjee, N. Mor, M. Vijayanunni, S. Mankad, R. Lall, and H. Sankaran. 2011. *Report on Indian Urban Infrastructure and Services*. New Delhi, India: Ministry of Urban Development.

Aklin, M., C.-Y. Cheng, J. Urpelainen, K. Ganesan, and A. Jain. 2016. "Factors Affecting Household Satisfaction with Electricity Supply in Rural India." *Nature Energy* 1 (11): 1–6.

Ambrus, A., E. Field, and R. Gonzalez. 2020. "Loss in the Time of Cholera: Long-Run Impact of a Disease Epidemic on the Urban Landscape." *American Economic Review* 110 (2): 475–525.

Anderson, S., and J.-M. Baland. 2002. "The Economics of Roscas and Intrahousehold Resource Allocation." *Quarterly Journal of Economics* 117 (3): 963–95.

Anderson, S., and M. Eswaran. 2009. "What Determines Female Autonomy? Evidence from Bangladesh." *Journal of Development Economics* 90 (2): 179–91.

Anukriti, S., C. Herrera-Almanza, P. K. Pathak, and M. Karra. 2020. "Curse of the Mummy-ji: The Influence of Mothers-in-Law on Women in India." *American Journal of Agricultural Economics* 102 (5): 1328–51.

Ashraf, N., E. Glaeser, A. Holland, and B. M. Steinberg. 2017. *Water, Health and Wealth.* Technical report. National Bureau of Economic Research. Cambridge, MA.

Bai, J., S. Jayachandran, E. J. Malesky, and B. A. Olken. 2019. "Firm Growth and Corruption: Empirical Evidence from Vietnam." *Economic Journal* 129 (618): 651–77.

Balasubramaniam, D., S. Chatterjee, and D. B. Mustard. 2014. "Got Water? Social Divisions and Access to Public Goods in Rural India." *Economica* 81 (321): 140–60.

Banerjee, A., L. Iyer, and R. Somanathan. 2005. "History, Social Divisions, and Public Goods in Rural India." *Journal of the European Economic Association* 3 (2–3): 639–47.

Bartram, J., K. Lewis, R. Lenton, and A. Wright. 2005. "Focusing on Improved Water and Sanitation for Health." *The Lancet* 365 (9461): 810–2.

Blakeslee, D., R. Fishman, and V. Srinivasan. 2020. "Way Down in the Hole: Adaptation to Long-Term Water Loss in Rural India." *American Economic Review* 110 (1): 200–24.

Chatterjee, E., S. Desai, and R. Vanneman. 2018. "Indian Paradox: Rising Education, Declining Womens' Employment." *Demographic Research* 38: 855.

Choudhuri, P., and S. Desai. 2021. "Lack of Access to Clean Fuel and Piped Water and Children's Educational Outcomes in Rural India." *World Development* 145: 105535.

Dang, D. A., and H. A. La. 2019. "Does Electricity Reliability Matter? Evidence from Rural Vietnam." *Energy Policy* 131: 399–409.

Das, M. B. 2017. *The Rising Tide: A New Look at Water and Gender*. World Bank. Washington, DC.

Dehury, B., and S. K. Mohanty. 2017. "Multidimensional Poverty, Household Environment and Short-Term Morbidity in India." *Genus* 73 (1): 1–23.

Desai, S., and R. Vanneman. 2018. *National Council of Applied Economic Research, New Delhi. India Human Development Survey (IHDS), 2012.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research, University of Michigan.

Dhanaraj, S., and V. Mahambare. 2019. "Family Structure, Education and Women's Employment in Rural India." *World Development* 115: 17–29.

Dinkelman, T. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101 (7): 3078–108.

Duflo, E. 2012. "Women Empowerment and Economic Development." *Journal of Economic Literature* 50 (4): 1051–79.

Ferrant, G., L. M. Pesando, and K. Nowacka. 2014. *Unpaid Care Work: The Missing Link in the Analysis of Gender Gaps in Labour Outcomes.* Boulogne Billancourt: OECD Development Center.

Ferrant, G., and A. Thim. 2019. *Measuring Women's Economic Empowerment: Time Use Data and Gender Inequality.* Technical report. OECD Publishing. Paris.

Fletcher, E., R. Pande, and C. M. T. Moore. 2017. *Women and Work in India: Descriptive Evidence and a Review of Potential Policies.* HKS Faculty Research Working Paper Series RWP18-004. Cambridge, MA: Harvard Kennedy School.

Galiani, S., P. Gertler, and E. Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113 (1): 83–120.

Hill, E., and L. Ma. 2017. "Shale Gas Development and Drinking Water Quality." *American Economic Review* 107 (5): 522–25.

Hulland, K. R., R. P. Chase, B. A. Caruso, R. Swain, B. Biswal, K. C. Sahoo, P. Panigrahi, and R. Dreibelbis. 2015. "Sanitation, Stress, and Life Stage: A Systematic Data Collection Study among Women in Odisha, India." *PloS One* 10 (11): e0141883.

Ilahi, N., and F. Grimard. 2000. "Public Infrastructure and Private Costs: Water Supply and Time Allocation of Women in Rural Pakistan." *Economic Development and Cultural Change* 49 (1): 45–75.

Jain, S. K. 2011. "Population Rise and Growing Water Scarcity in India—Revised Estimates and Required Initiatives." *Current Science* 101 (3): 271–6.

Jalan, J., and M. Ravallion. 2003. "Does Piped Water Reduce Diarrhea for Children in Rural India? *Journal of Econometrics* 112 (1): 153–73.

Jayachandran, S. 2019. *Social Norms as a Barrier to Women's Employment in Developing Countries.* Institute for Policy Studies, Northwestern Working Paper 19–31. Evanston, Illinois.

Jessoe, K. 2013. "Improved Source, Improved Quality? Demand for Drinking Water Quality in Rural India." *Journal of Environmental Economics and Management* 66 (3): 460–75.

Klasen, S. 2019. "What Explains Uneven Female Labor Force Participation Levels and Trends in Developing Countries?" *World Bank Research Observer* 34 (2): 161–97.

Koolwal, G., and D. Van de Walle. 2013. "Access to Water, Women's Work, and Child Outcomes." *Economic Development and Cultural Change* 61 (2): 369–405.

Kumar, S., and S. Vollmer. 2013. "Does Access to Improved Sanitation Reduce Childhood Diarrhea in Rural India?" *Health Economics* 22 (4): 410–27.

Malakar, K., T. Mishra, and A. Patwardhan. 2018. "Inequality in Water Supply in India: An Assessment Using the Gini and Theil Indices." *Environment, Development and Sustainability* 20 (2): 841–64.

Mani, S., T. Shahidi, S. J. Patnaik, J. Sasmita, A. Tripathi, G. Saurabh, M. Aklin, J. Urpelainen, and N. Chindarkar. 2018. *Access to Clean Cooking Energy and Electricity: Survey of States in India 2018 (ACCESS 2018).* Council on Energy, Environment and Water. New Delhi.

McKenzie, D., and I. Ray. 2009. "Urban Water Supply in India: Status, Reform Options and Possible Lessons." *Water Policy* 11 (4): 442–60.

Meeks, R. C. 2017. "Water Works: The Economic Impact of Water Infrastructure." *Journal of Human Resources* 52 (4): 1119–53.

O'Reilly, K. 2006. "'Traditional' Women, 'Modern' Water: Linking Gender and Commodification in Rajasthan, India." *Geoforum* 37 (6): 958–72.

Pelz, S., N. Chindarkar, and J. Urpelainen. 2021. "Energy Access for Marginalized Communities: Evidence from Rural North India, 2015–2018." *World Development* 137: 105204.

Rathi, S. S., and C. Vermaak. 2018. "Rural Electrification, Gender and the Labor Market: A Cross-Country Study of India and South Africa." *World Development* 109: 346–59.

Ravallion, M. 2008. *Evaluation in the Practice of Development.* The World Bank. Washington, DC.

Schmidt, J. J. 2020. "Pop-Up Infrastructure: Water ATMs and New Delivery Networks in India." *Water Alternatives* 13 (1): 119–140.

Schultz, T. P. 2001. "Women's Roles in the Agricultural Household: Bargaining and Human Capital Investments." *Handbook of Agricultural Economics* 1: 383–456.

Sedai, A. K., R. Nepal, and T. Jamasb. 2020. "Flickering Lifelines: Electrification and Household Welfare in India." *Energy Economics*: 104975.

Sedai, A. K., R. Vasudevan, A. A. Pena, and R. Miller. 2021. "Does Reliable Electrification Reduce Gender Differences? Evidence from India." *Journal of Economic Behavior & Organization* 185: 580–601.

Staiger, D., and J. H. Stock. 1997. "Instrumental Variables Regression with Weak Instruments." *Econometrica* 65 (3): 557–86.

UNICEF. 2012. *Pneumonia, Diarrhoea—Tackling the Deadliest Diseases for the World's Poorest Children.* New York, NY: UNICEF.

———. 2016. *Collecting Water is Often a Colossal Waste of Time for Women and Girls.* Press release. New York.

Vanaja, S. 2020. "Essays on the Time Use and Behavioral Patterns of Women's Access to Household Water in Rural India." Diss. Tata-Cornell Institute.

Wardlaw, T., P. Salama, C. Brocklehurst, M. Chopra, and E. Mason. 2010. "Diarrhoea: Why Children Are Still Dying and What Can Be Done." *The Lancet* 375 (9718):870–2.

Wescoat Jr, J. L., S. Fletcher, and M. Novellino. 2016. "National Rural Drinking Water Monitoring: Progress and Challenges with India's IMIS Database." *Water Policy* 18 (4): 1015–32.

World Health Organization (WHO) (2009). *Diarrhoea: Why Children Are Still Dying and What Can Be Done*.

Wu, X., R. Schuyler House, and R. Peri. 2016. "Public–Private Partnerships (PPPs) in Water and Sanitation in India: Lessons from China." *Water Policy* 18 (S1): 153–76.

Zérah, M.-H. 2000. *Water, Unreliable Supply in Delhi*. Manohar Publishers. New Delhi.

Ziegelhofer, Z. 2012. *Down with Diarrhea: Using Fuzzy Regression Discontinuity Design to Link Communal Water Supply with Health*. Technical report. Graduate Institute of International and Development Studies Working Paper. Geneva.